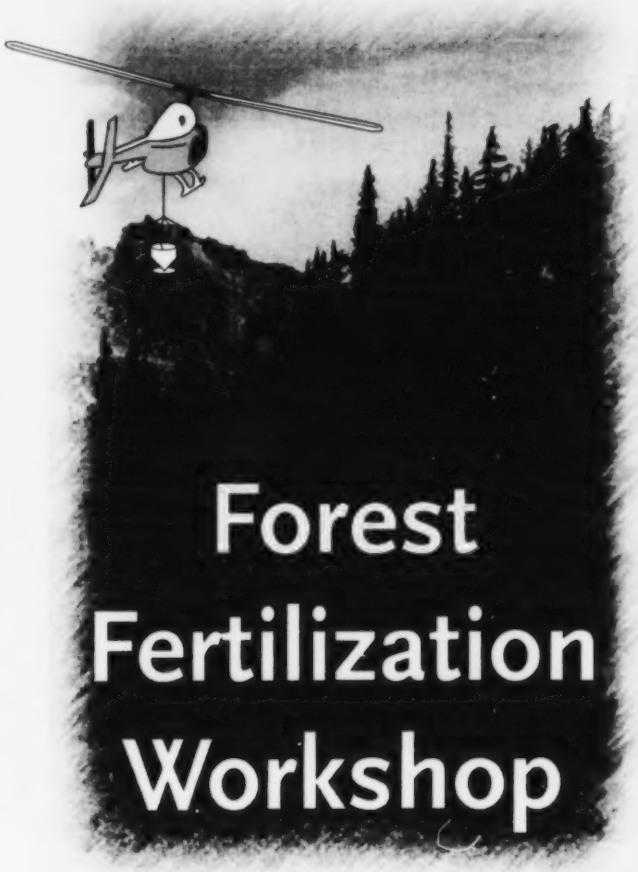

Forest Fertilization Workshop

Modular Based Training

Participant's Workbook

FOREST RENEWAL BC

BRITISH COLUMBIA

Ministry of Forests
Forest Practices Branch

106-0 5786 /

Acknowledgements

Thanks are extended to Rob Brockley with the Ministry of Forests' Kalamalka Research Station; Reid Carter, formerly with TimberWest Forest Ltd.; and Mel Scott at the Forest Practices Branch, Ministry of Forests, for their assistance and advice in producing this course material. As well, Mike Fidgeon, Ron Gray, Guy Newsome, Ivan Listar, Les Herring and Lou Tromp, all from the Ministry of Forests, contributed comments and suggestions on a pilot version of the course material. Frank Barber, of the Ministry of Forests, Forest Practices Branch, Bryce Bancroft of Symmetree Consulting Group Ltd. and Jane Perry, forestry consultant, updated the facilitator's guide and participant's workbook to produce these revised editions. TM Communications is gratefully acknowledged for final compilation and production. Funding for this course material was provided by Forest Renewal BC.

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INTRODUCTION

Lesson 1: Workshop Introduction

Purpose

The purpose of this workshop is to provide you with an overview of planning and operations for forest fertilization programs and projects through clarification of the use, intent and requirements of the *Forest Fertilization Guidebook* and the associated legislation and regulations under the Forest Practices Code. This workbook has been designed to accompany the facilitator's guide; it follows the workshop format and includes the overheads presented with space for your own notes. Please note that practitioners involved in forest fertilization should always refer to the current legislation to ensure that they are using the most recent references.

This workshop will spend roughly half a day each on fertilization planning and operations. Your facilitator will present the workshop through a series of lecturettes with overheads along with case studies and group discussion. Your participation is encouraged for your comprehension and enjoyment of the workshop. There may be an accompanying field trip that will help to reinforce the material presented.

The workshop is modular in design with lesson plans for each session. Much of the course material is based on the *Forest Fertilization Guidebook*. Additional reference and technical information outside of the Forest Practices Code is provided to ensure that the workshop extends beyond only the guidebook material. The instruction is mostly through lecturettes by the facilitator using overheads, along with group discussions, case studies and viewing a video. Several exercises are also included to self-test your understanding of the material. At the beginning of the workshop, the course facilitator will inform participants of the lessons to be covered and the timetable that will be followed.

Agenda

Session	Lesson	Time
	Registration	8:00–8:30
Introduction	Workshop Overview	8:30–8:45
	Introduction to Forest Fertilization	8:45–9:30
Program Planning	Forest Fertilization Program	9:30–10:15
	Break	10:15–10:30
	Biological Factors	10:30–11:10
	Operational Factors	11:10–11:30
	Stand Selection	11:30–Noon
	Lunch	Noon–1:00
Operations	Foliar Analysis	1:00–1:40
	Contract Administration	1:40–2:15
	Operational Fertilization	2:15–3:15
	Break	3:15–3:30
	Monitoring Programs	3:30–4:00
	Questions and Wrap-Up	4:00–4:30

Target Audience

This workshop will be of interest and use to industry, government and consulting personnel responsible for preparing, implementing or monitoring prescriptions and contracts for fertilization.

Workshop Objectives

- **Introduction**
- **Strategic purpose**
- **Basic conditions**
- **Stand selection, evaluation and ranking**
- **Fertilization plans**
- **Foliar analysis**
- **Contract administration**
- **Forest Practices Code**
- **Operations**
- **Correct and safe application and monitoring**

Notes:

Lesson 2: Introduction to Forest Fertilization

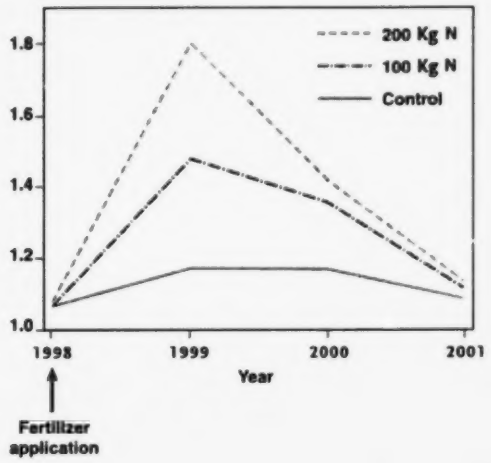
Growth Response to Fertilization

N → N

Mineralized 2–3%

Notes:

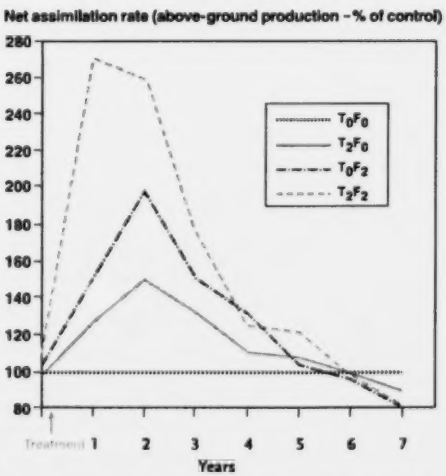
Foliar Nitrogen



Notes:

Response to Fertilization

Net Assimilation Rates



Net assimilation rates by years based on total above-ground dry matter production.

* Rates with thinning and fertilizer treatments are expressed as % of rate for control.

Notes:

Foliar Biomass Increases

Foliar biomass increases five years post-treatment (adapted from Brix, 1981)

	Treatments			
	Control	Thinned	Fertilized	Thinned and Fertilized
Total # of needles	21 000	30 600	60 100	68 300
# of shoots	269	326	572	750
Needles/shoot	78	94	105	91
Ave. shoot length (cm)	4.58	4.81	5.76	5.12
Needle density (#/cm)	16.3	18.8	17.1	16.7
Total needle weight (g)	82.8	132.0	247.3	305.0
1000 needle weight (g)	3.95	4.31	4.11	4.47

Operational Planning Regulation

Part 6 – Stand Management Prescriptions

Treatments and objectives for treatments

49. (1) For the purposes of section 24(2.1) of the Act, the treatments may be one or more of the following:

- **(c)** fertilization

Content of stand management prescriptions

50. (3) A stand management prescription must, for each standards unit, specify all of the following:

- **(j)** if the proposed treatment is fertilization,
- **(i)** the type of fertilizer,
- **(ii)** the rate of application,
- **(iii)** the method of application,
- **(iv)** the season the proposed treatment is to be carried out, and
- **(v)** if in a community watershed, the known water quality objectives.

Notes:

Silviculture Practices Regulation

Division 3 – Stand Management

Use of fertilizers

21. (1) A person who carries out a silviculture treatment and uses fertilizer must store, handle and apply the fertilizer in a manner that protects forest resources.

(2) A person who carries out a silviculture treatment and who applies fertilizer other than on spot areas in a community watershed must not

(a) apply fertilizer

(i) closer than 100 m upslope of a water intake, or

(ii) within 10 m of a perennial stream that is observable from the air, at the height the fertilizer will be applied, unless otherwise authorized by both the district manager and the Minister of Health, and

(b) cause

(i) nitrate nitrogen levels in a stream to exceed 10 ppm measured immediately below the area where the fertilizer is applied,

(ii) chlorophyll levels to exceed

(a) 2 micrograms/litre in a lake, or

(b) 5 milligrams/square metre in a stream, or

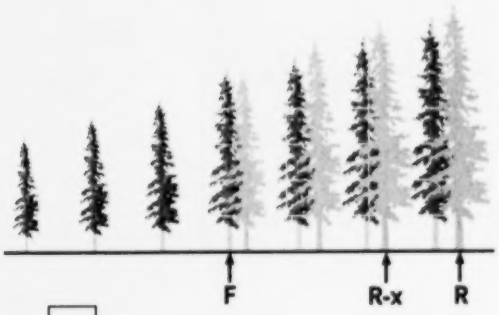
(iii) water quality to fall below any known water quality object

Notes:

PROGRAM PLANNING

Lesson 3: Forest Fertilization Program

Fertilization as a Strategic Tool



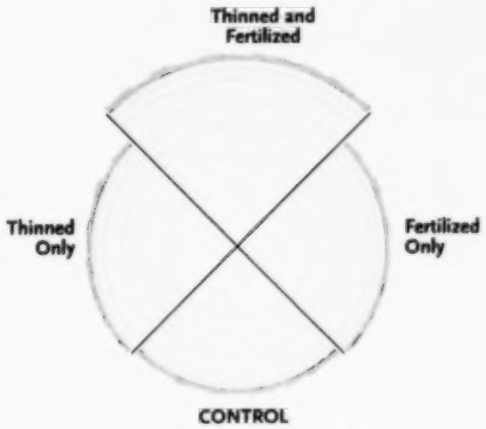
F – Fertilized trees get boost in growth

R-x– rotation size can be reached sooner through fertilization.

R – fertilization yields larger trees at natural rotation age.

Notes:

Response to Fertilization



Notes:

Questions to Participants

1. Do you have defined investment priorities for the funds you spend on fertilization? If not, how should priorities be determined to set up the program?
2. Do you have defined stand targets for determining the rotation age of different tree species across all sites? If not, how would you go about defining them?
3. How would you determine either the reduction in the rotation age or the increase in wood volume from fertilization treatments?
4. How would you decide if you have sufficient land area by age class to fertilize and have a significant impact on the wood supply?
5. What operational falldown factor do you apply to the research results for modeling stand response from fertilization?
6. What should be part of a long-term monitoring plan for the measurement of growth response to fertilization?

Notes:

Forest Fertilization Case Study (Coast)

The private land base of this managed forest consists of approximately 80 000 ha of forested land. The even-flow, long-run sustainable rate of harvest is estimated at 375 000 m^3 if these lands were unmanaged. The management practices employed to date and currently used – such as immediate reforestation, achieving free growing status, conducting juvenile spacing, and fertilization at the time of spacing – are expected to sustain a harvest of 415 000 m^3 which could be increased to 450 000 m^3 in 2038.

The company's long-term wood requirements indicate that within 20 years, and due to the expiration of Old Temporary Tenure licenses, the harvest from these private lands should be closer to 500 000 m^3. However, simulations with a forest estate model indicate that this level of harvest is not sustainable with current practices. To reach this target it has been determined that the management strategy must include fertilizing 4000 ha/year of stands about 10 years before harvest. The estimated gain in volume from this strategy is approximated at 15 m^3/ha or a total gain of 60 000 m^3 of harvest volume. This treatment should take place starting immediately and continue for the next two decades. Such a management strategy has been shown to allow the harvest of 480 000 m^3/year through to 2038 and an increase to approximately 500 000 m^3/year thereafter. This cut level could then be maintained indefinitely, provided such a program of fertilization was repeated again during the period of 2080 and 2090, thereby offsetting a projected deficit anticipated to occur during the period 2095 and 2104.

It is expected that fertilization approximately 10–15 years before harvest should accelerate the growth of the stand and help overcome a projected wood supply problem by producing 15 m^3/ha greater yield at 60 years of age. The diameter distribution after the treatment would shift stems into the merchantability category and increase the stand average diameter by about 3 cm. The range of diameters is reduced because increased between-tree competition will remove numbers of smaller understory trees. Harvest costs will be reduced because fewer trees will be handled.

Summary

Forest fertilization is a silvicultural treatment that must be applied with discretion and proof that it is an appropriate strategy for the wood supply problem. It requires a strong guarantee of security over the land base so that the benefits can be counted on for the near and longer term. It works best where there is a stand-based information system that can relate to the future wood supply needs and harvest scheduling. Finally, there is a need for reliable growth and yield information to assist in prescribing the most effective and timely application of the fertilization treatments.

Notes:

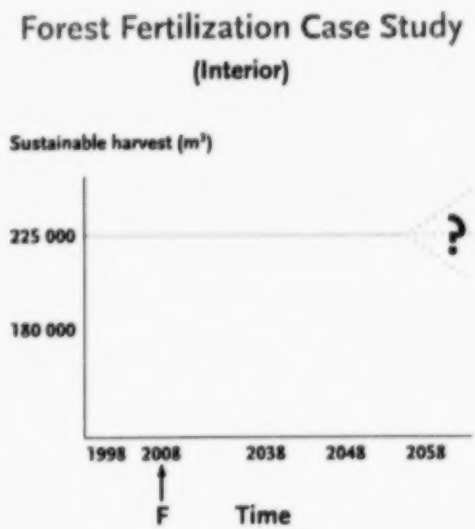
Interior Forest Fertilization Case Study

A typical age class structure of many interior forest management units consists of a substantial area of young stands and a large area of old growth stands with little or no area in the intermediate age classes. The development of the forest age-class structure resembles a wave, with a harvest level in the near term based on the reduction of the initial standing old growth. If this rate exceeds the time necessary for the current young stands to develop into merchantable stands, there is a sudden and rapid timber supply falldown in the future.

Even if the rate of harvest is sufficient to allow the young stands to grow to merchantable size, these "new" harvestable stand types will typically have less standing volume than the previous old-growth stands because the age at which a stand is scheduled for harvest will probably be the culmination of mean annual increment and not the point of maximum standing volume. This is a simplified explanation of the falldown effect so common to the province's forest management units.

In this example, without forest fertilization, the harvest volume cannot be sustained at 225 000 m^3/year past 60 years in the future, after the year 2058. This is not simply because the second growth stands were not given sufficient time to reach merchantability; in fact, some second growth stands are harvested as earlier as 41 years from present. The reasons are that some of the stands in the oldest age classes are assumed to be lost to insects and diseases. These stands recycle back on to the regenerated yield curve but have not provided any volume to the harvest. As well, the standing volume of the regenerated stands when harvested up to 50 m^3/ha less than that of the old growth stands.

Clearly, the only way to maintain the present harvest level of 225 000 m^3 is to apply those silvicultural treatments that will result in earlier merchantability and greater volume at a younger age. Before reading further, sketch the shape of the volume over age curve on the curve shown for this base case. What is the magnitude of the differences?



The application of fertilizer to only 50% of the stands was found to be adequate to bridge the wood supply problem at 60 years from the present. The shape of the yield curve assigned to this treatment and the stand types to which it was applied are known. The effect of the fertilization is represented in the diagrams and described as follows: **The fertilization yield curve does not give more volume per hectare, but rather it produces a similar volume at a younger age and reduces the age of merchantability.** This is a basic tenet of forest fertilization as a silvicultural treatment for reducing projected timber supply falldowns.

The age-class structure develops much as before for the initial 40 years, except that now as the initial harvested area begins at 1 000 ha/year it can quickly increase with the availability of the fertilized stands reaching merchantability sooner. Now the second growth stands that are harvested 41 years from present have standing volumes similar to stands 15 to 20 years older. The fact that 50% of the second growth stands now have volumes similar to the pre-existing old growth stands means that the area harvested does not need to increase as much. The one caveat that should be mentioned, however, is that the fertilized stands are preferentially harvested in the initial stages. The repercussions of this policy is that when the unfertilized second growth stands are harvested, at least half of them will have to be fertilized to perpetuate this strategy. Therefore, the entire forest is assumed to consist of potential fertilization candidate stands, an unlikely occurrence in many areas.

In summary, different forest estates have different opportunities to maintain or increase timber supply from a strategically-planned forest fertilization program. There is also the potential from fertilization to maintain revenue to the Crown from timber harvesting while harvesting less area because each fertilized hectare of forest is producing more volume.

Notes:

Stand Management Prescription

- **Use Section D-1 Post-treatment Standards**
- **Fertilization included as treatment under 'Schedule'**

Year	Age/ Height	DBH	Treatment	Area (ha)
1996	18/7	6.5	Juvenile space 800 sph	22.7
1997	19/7.5		Prune	22.7
1998	20/8.6	9.2	Fertilize @ 250 kg N/ha	24.0
2002	24/11.5	15.6	Prune	22.7
2005	27/13	19	Fertilize @ 250 kg N/ha	24.0
2038	60/30	37	Harvest	22.7

For more information refer to the *Stand Management Prescription Guidebook* (1999)

Notes:

Lesson 4: Biological Factors

Biological Factors

Notes:

Biological Factors

- Species
- Age and size
- Stand density
- Soil moisture and nutrient regimes
- Site quality
- Crown condition
- Nutrient diagnosis
- Insects, disease and small mammal damage

Notes:

Coastal Species

Douglas-fir **Western hemlock** **Sitka spruce**

√ ? (√)

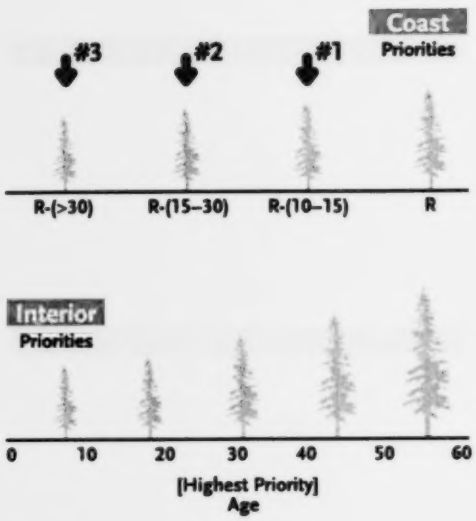
Interior Species

Lodgepole pine **Wetbelt Douglas-fir**

√* (√)

Notes:

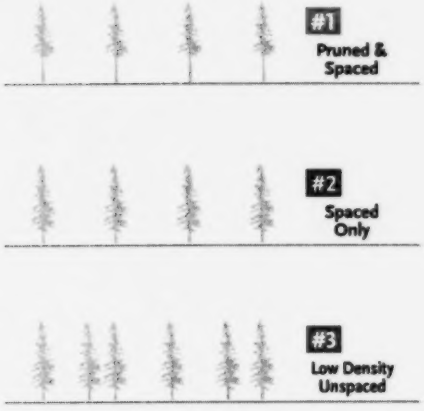
Age



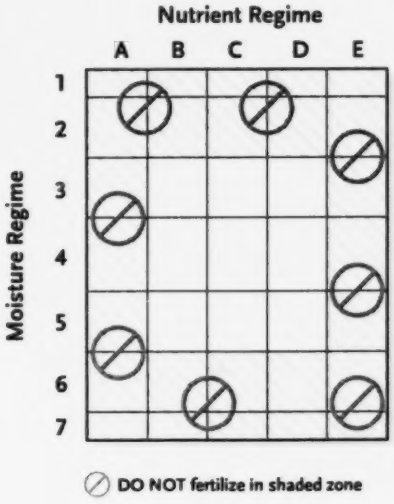
R = Response
(>30) = Number of years for response to occur.

Notes:

Stand Density

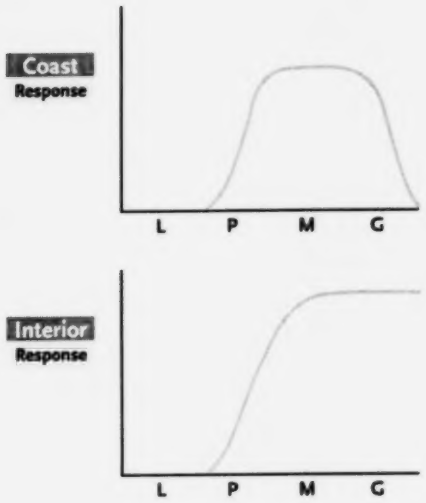


Soil Moisture and Nutrient Regimes



Notes:

Site Quality

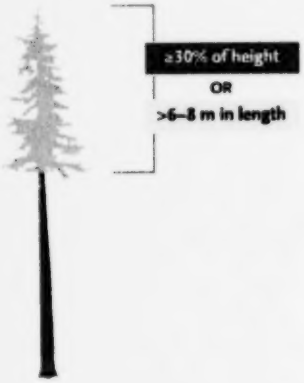


Relative vs. Absolute Growth

	Site Class	
	Low	Medium
Merchantable volume	100 m^3	250 m^3
% increase due to fertilization	20%	20%
Absolute increase	20 m^3	50 m^3

Notes:

Crown Condition



Visual Symptoms

Notes:

Nutrient Diagnosis

Forest Fertilization Workshop 4 - 12

Forest Health

- Overall interaction between forest fertilization and forest health agents is poorly understood
- Current damage may increase
- Outgrow small mammal damage?
- Interaction from associated treatments?
- Local experience
- Forest health specialists

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Notes:

Lesson 5: Operational Factors

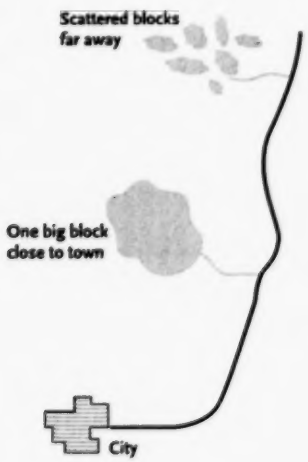
Operational Factors

Notes:

Operational Factors

- **Location**
- **Access**
- **Slope**
- **Project and block size**

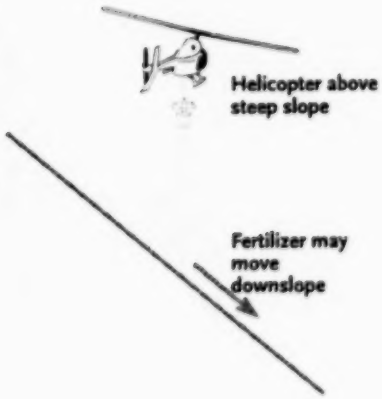
Location



Notes:

Access

Slope



Notes:

Project and Block Size

Notes:

Lesson 6: Stand Selection

Coastal Douglas-fir Case Study

Scenario: You are a silviculturist in the Sunshine Coast forest district. You have been asked to evaluate the following stand of Douglas-fir for inclusion in an aerial fertilization program which currently consists of 630 hectares.

Stand Data: The inventory database and the silviculture history records provide you with the following:

Total area:	120 ha
Dominant tree species:	Douglas-fir (Fd)
Minor tree species:	western redcedar (Cw) < 10%
BEC subzone:	CDFmm
Site association:	Douglas-fir – Salal
Estimated site class:	Medium (SI = 25 m)
Establishment history:	Planted in 1950 with Fd 2+0 BR
Stand tending history:	Spaced in 1980 to 800 sph
Other:	No insect, disease or wildlife concerns

* All the operational factors and strategic objectives are acceptable for the stand.

What should you do next to determine the ranking for a fertilization treatment of this stand?

Notes:

Interior Lodgepole Pine Case Study

Scenario: You are a silviculturist in the Prince George forest district. You have been asked to evaluate the following stand of lodgepole pine for inclusion in an aerial fertilization program which currently consists of 630 hectares.

Stand Data: The inventory database and the silviculture history records provide you with the following:

Total area:	120 ha
Dominant tree species:	Lodgepole pine (Pl)
Minor tree species:	White spruce (Sw) < 10%
BEC subzone:	SBSmk
Site association:	Bunchberry-moss (01)
Estimated site class:	Medium (SI = 19 m)
Establishment history:	Planted in 1970 with Pl 1+0 BR
Stand tending history:	Spaced in 1990 to 1200 sph
Other:	No insect, disease or wildlife concerns

* All the operational factors and strategic objectives are acceptable for the stand.

What should you do next to determine the ranking for a fertilization treatment of this stand?

Notes:

Which stand would you rather fertilize and why?

	Stand #1	Stand #2
Species	Pl70 Sx30	Pl60 Sx30 At10
Age	40 years	50 years
Density	1000 wsph (JS 1984)	1400 total sph, Pl and Sx dominants with aspen in clumps
Ecosystem	SBSdk 05 submesotrophic	SBSdk 01 mesotrophic
Site index	SI_{50} 18	SI_{50} 22
Forest health	< 5% insect and disease damage	< 5% insect and disease damage
Access	Road washed out, need to rebuild bridge	Good access, near mainline
Slope	avg. 15%	avg. 5%
Block size	120 ha	320 ha of cumulative blocks

Which stand would you rather fertilize and why?

	STAND #1	STAND #2
Species	Pl70 Sx30	Pl60 Sx30 At10
Age	40 years	50 years
Density	1000 wsph (JS 1984)	1400 total sph Sx dominants with aspen in clumps
Ecosystem	SBSdk 05 submesotropic	SBSdk 05 mesotropic
Site Index	SI_{50} 18	SI_{50} 22
Forest Health	<5% insect and disease damage	<5% insect and disease damage
Access	Road washed out, need to rebuild bridge	Good access, near mainline
Slope	avg. 15%	avg. 15%
Block Size	120 ha	320 ha of cumulative blocks

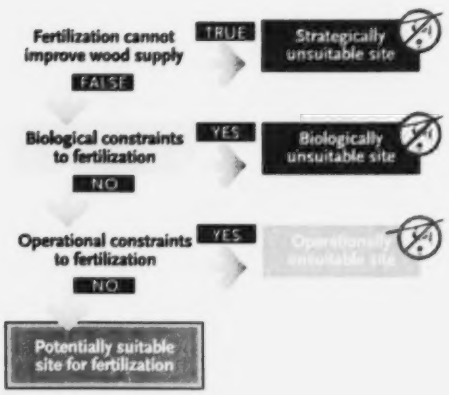
Notes:

Site Constraint Factors Exercise

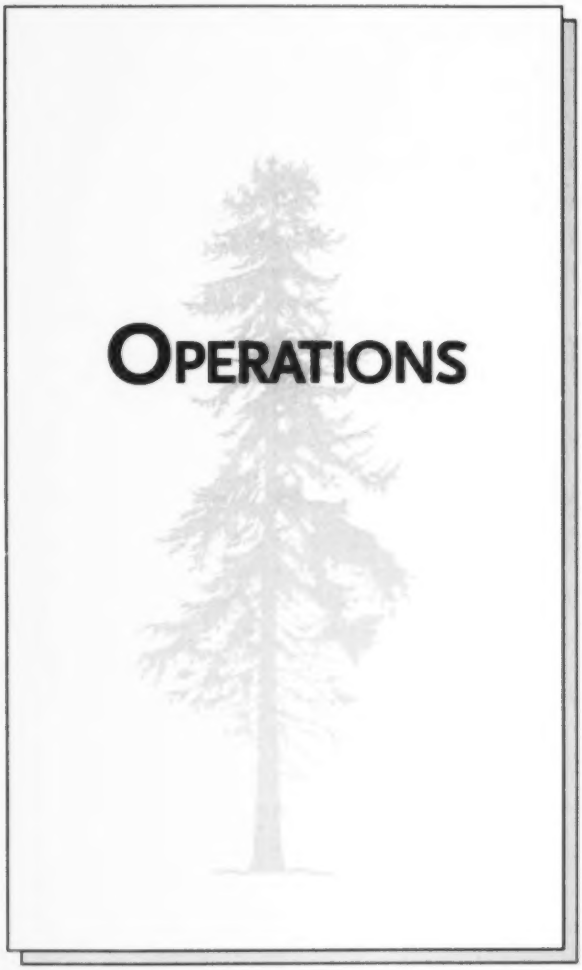
State whether the constraint factor is wood supply/strategic (S), biological (B) or operational (O) from the following site descriptions:

- ☐ Soil moisture regime is very dry
- ☐ Site is located on a small island in Johnstone Strait
- ☐ Squirrel damage is evident in adjacent stands
- ☐ Site has a fluctuating water table
- ☐ Average slope is 35% with broken terrain
- ☐ Soil temperature rarely exceeds 10°C
- ☐ Limestone rock outcrops are common
- ☐ Roads and bridges into blocks are subject to washouts
- ☐ Rooting depth is < 30 cm
- ☐ Falldown has not been factored into Timber Supply Review
- ☐ Mineralizable-N rate is high
- ☐ Stand is situated on an active alluvial plain
- ☐ Visual green-up requirements restrict harvest opportunities
- ☐ Inventory database shows few Douglas-fir leading species stands in the management unit

Stand Selection Process



Notes:



OPERATIONS

Lesson 7: Foliar Analysis

Notes:

Foliar Sampling Guidelines

- Sample in the fall
- Sample only dominants and co-dominants

Foliar Sampling Guidelines (con't)

Notes:

Foliar Analysis

Pre-fertilization

- Composite samples from representative locations
- Stratify samples if necessary
- Complete laboratory analysis

Post-fertilization

- Needle weights
- Representative locations across flight lines
- Complete laboratory analysis

* Contact regional Stand Tending Forester or Rob Brockley, Kalamalka Research Station

Notes:

Lesson 8: Contract Administration

Fertilization Program Time Line

Notes:

Community Watersheds

- **Specific designation**
- **Up to 30% per year with buffers as specified in guidebook, or maximum 12% of total area**
- **100 m buffer above water intakes**

Notes:

Lesson 9: Operational Fertilization

Checklist for Operational Fertilization Projects

Project Title: _____
File #: _____

	STEP	TASKS / SUGGESTIONS	✓
1	Cutblock identification	Collect data on strategic, biological and operational considerations, including economy of scale for a series of blocks to constitute a project (best >500 ha). Use operational plans, maps, electronic record systems, road recces, foliar analysis, screening trials to identify potential stands	
2	Tender package preparation	Tender package should include:	
		▫ Updated maps	
		▫ Aerial photos showing cutblocks for fertilization, stream buffers, No Treatment zones, road access	
		▫ Clear, self-explanatory contract specifications	
		▫ Minimum standards of equipment and safety	
		▫ Spill Contingency Plan/Clean-up requirements	
		▫ Personnel skills	
		▫ Application techniques required	
		▫ Concerns if fertilizing in a community watershed	
3	Advertise, review proposals, award contract	Advertising should cover British Columbia, Alberta, Saskatchewan, Washington, Oregon and Idaho	
4	Pre-work conference	Review all details with the contractor on:	
		▫ Safety	
		▫ Spill Contingency Plan/Clean-up requirements	
		▫ Personnel	
		▫ Application specifics	
		Review **Fertilization Pre-Work Checklist**	
5	Staging (equipment mobilization, road upgrading)	Plans in place between contractor and district or licensee for any necessary access improvements	
6	Cutblock boundaries	Mark all buffer strips around reserves, streams, edges and No Treatment zones using paper rolls, balloons or other methods	
7	Calibration of application rates	Calibrate application rate of fertilizer from spreader to ensure prescribed application rate of fertilizer/ha is applied	
8	Monitoring of fertilizer application	Monitor application rate, buffers, spills, waterbodies using on-site viewing of application (swath wide/overlap) and missed patches. Check for prill in buffers, streams and other No Treatment zones	
9	Monitoring of water quality	As outlined in *Forest Fertilization Guidebook*	
10	Contract payment	Review all phases of contract when work completed to determine appropriate payment	
11	Reporting	Report all treated blocks on electronic record system	

Notes:

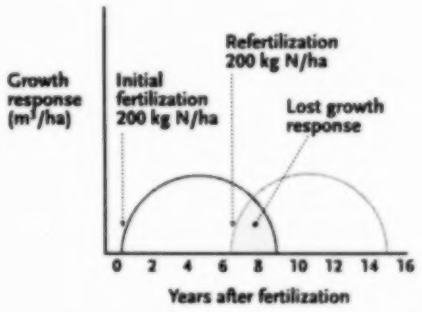
Refertilization

- Refertilization before the initial application response terminates reduces the potential total growth response
- Response is sustained longer with repeat treatments over one treatment

General Rule

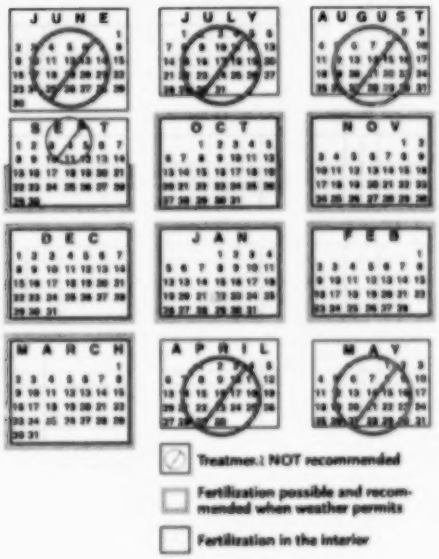
- Coast – Refertilize every 8–10 years
- Interior – Refertilize every 5–7 years

Refertilization


Growth response (m³/ha)
Initial fertilization 200 kg N/ha
Refertilization 200 kg N/ha
Lost growth response
0 2 4 6 8 10 12 14 16
Years after fertilization

Notes:

Season of Application



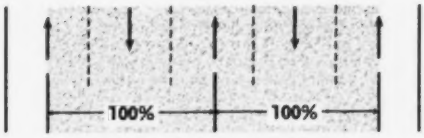
Monitoring Plan Checklist

- Loading sites cleaned
- Flight paths, flying procedures, radio traffic, fertilizer application
- Weather and flying conditions
- Check perpendicularly to flight lines for even coverage, prescribed overlap and no gaps
- Block boundaries, buffer zones and No Treatment areas
- Monitor the cumulative weight of fertilizer spread

Notes:

Calibration

- Important to ensure prescribed application rate
- Test run when project begins
- Check periodically
- Contractor should be familiar with calibration and confident with application rate
- Proper application is in contractor's best interest!



* 50% application on each flight line adds up to 100% application when flight lines overlap

On-site Documents

- Contingency plan for fertilizer spills
- Material Safety Data Sheet (MSDS) for fertilizer
- Fertilization contract with maps showing buffer areas
- Silviculture Prescription/ Stand Management Prescription

Notes:

Contingency Plan

- Name and phone number for contacts in the:
  - Ministry of Health
  - Ministry of Forests
  - Ministry of Environment, Lands and Parks
  - Ministry of Transportation and Highways
  - Regional District
  - RCMP

- Necessary to inform that clean-up is in progress
- Contingency plan available in vehicles

Notes:

Lesson 10: Monitoring

Monitoring Objectives

- Site selection – Monitoring guidelines
- Quality control – Monitoring operations
- Response measurement – Monitoring stand behaviour after treatment
- Past efforts have focused at the stand level
- Monitoring how, and how well, site selection and operations have been conducted is useful to judge effectiveness of fertilization program

Notes:

Fertilizer Application Monitoring

Objectives

- Define acceptable accuracy standards to:
  - Monitor contractor performance
  - Document for treatment records
- Aim for +/- 10% accuracy

Estimation of Fertilizer Application Rate

Total amount of fertilizer applied/size of area

- No estimate of variability

Sample traps

- Use only in open areas
- Cumbersome and time consuming
- No information on swath width or overlap
- Fertilizer may bounce out
- Large number of traps required
- Use in control and fertilized plots to compare

Measurement of swath width and overlap on ground

- Quick and easy
- No prill counting or weighing

Notes:

Growth Response Monitoring

- Install operational plots ("short-term" PSPs)
- Monitoring essential to supplement research but cannot substitute for it
- Appropriate monitoring strategy will depend on treatment objectives
- Confirm and document methodology and responsibilities prior to the fertilization treatment
- Representative control blocks must be established before fertilization
- Establish database in each district to note response trends

Notes:

Notes:

Appendix

Appendix: Forest Fertilization and Management Objectives

Note: Workshop participants are encouraged to explore the information presented in this appendix to further their background knowledge of forest fertilization planning.

The opinions of a person outside of our country can sometimes provide a different and unique perspective of the situation, particularly when that country (Sweden) has significant experience with this forest management tool and its effects. The three postulates of Stig Hagner, Professor of Silviculture and Director of Forestry Operations, Svenska Cellulosa Ab., provide an opportunity to discuss if the conditions are suitable for forest fertilization in BC.

The following is a synopsis of a paper given by Professor Stig Hagner at the March, 1988 Forest Fertilization Workshop entitled "Improving Forest Fertilization Decision-making in British Columbia." His talk gave an overview of Sweden's fertilization experience and role in forest management. He suggested three postulates (prerequisites or fundamental conditions) regarding the basic conditions that forest fertilization must satisfy to be considered a suitable silviculture management treatment. The postulates are:

- The agency benefiting from the increased wood availability should fund its production.
- Forest fertilization should be integrated into an overall plan for long-term utilization of forest resoures, requiring that the agency planning to benefit has long-term security of tenure.
- Forest fertilization can be justified on economic grounds if, for forest owners who sell timber, the increased value of the selling price of the wood is greater than the cost to produce it. For forest owners also operating wood-processing facilities, the forest fertilization can be justified if it improves the industry's raw material supply position at a cost that permits profitable production, or allows for obtaining harvested timber from less expensive sources.

Think about these three postulates and put them in the perspective of British Columbia and its current state of forest management.

- Do you agree or disagree with Stig Hagner?
- With the high level of privately owned forest in Sweden (by small land owners and by the forest industry), how would a fertilization program in Sweden differ from that in British Columbia?
- What are the limiting factors to an expanded forest fertilization program in BC?
- How could BC's factors be modified to allow for an expanded program and the resulting benefits?
- In light of recent land use plans and zoning in BC through higher level plans, how could fertilization be used more beneficially?

Appendix: Foliar Analysis

Interpretation and Diagnosis Exercises

Consider each of the following scenarios and make interpretations on the possibility of the stand being affected by nutrient deficiencies. Identify possible deficiencies and explain which factor may be contributing to the occurrence of the foliar nutrient levels found.

Scenario 1

A young (7 to 10 year old) hemlock plantation in the Campbell River forest district is showing obvious signs of "checked height growth." The initial height growth following burning and plantation establishment was good (40–60 cm/year) and has now declined to less than 15 cm per year. The trees are growing on an old cedar-hemlock site with a surface organic horizon approximately 55 cm thick of decaying wood. Soil samples of this organic soil type (Folisolic Humoferric Podzol) show high C:N ratio, low mineralization rates and high probability of immobilization. The site has a fresh to moist SMR and poor SNR. Annual rainfall is approximately 2600 mm/year.

Foliage samples were collected as a composite sample of 15 trees during the dormant season of 1987. The following foliar nutrient levels were found:

	%		ppm
N	0.61	SO_4-S	214
P	0.13	Cu	4.3
K	0.78	Zn	26
Ca	0.52	Mn	957
Mg	0.08	Active Fe	66
S	0.07	B	18

What are the site factors likely contributing to the poor growth performance of this plantation? Is nitrogen fertilization likely to result in improved growth performance? What other nutrient(s) would you prescribe and would you expect to get a long-term growth response?

Answer:

Scenario 2

A 32 year old white spruce stand is growing in the Bowron River area of the Prince George Forest District. The site is very productive, the actual soil moisture regime is fresh to moist, and the actual soil nutrient regime is medium to rich. The understory vegetation is in the *Gymnocarpium–Oplopanax* plant association. The site is located at the toe of a long slope with the forest classified as a Mormoder and the mineral soil as an Orthic Eutric Brunisol approximately 1.5 m deep and moderately well drained. The annual height increment is 75–100 cm.

	%		ppm
N	1.22	SO_4-S	55
P	0.145	Cu	2.3
K	0.62	Zn	16
Ca	0.29	Mn	125
Mg	0.085	Active Fe	44
S	0.116	B	9

Is this stand likely to respond to fertilization? What nutrients are likely to be most deficient, if any? Are any site or stand factors important when considering the nutrient status of this stand?

Answer:

Scenario 3

A 22 year old lodgepole pine stand is located in the Anahim Lake area of the Chilcotin Plateau. The stand has developed on an outwash terrace, and the parent material mineralogy is acid igneous, primarily granodiorites and quartz-diorites. The forest floor is a thin Hemimor while the mineral soil is a well-drained coarse-textured gravelly loamy-sand. Annual precipitation is approximately 740 mm with a prolonged summer drought. This stand has been already spaced and fertilized with 225 kg N/ha as urea. These are the post-treatment foliar analysis results.

	%		ppm
N	1.29	SO_4-S	235
P	0.182	Cu	4.2
K	0.57	Zn	13
Ca	0.40	Mn	565
Mg	0.115	Active Fe	34
S	0.116	B	5.2

Is this stand likely to have responded to the nitrogen fertilization? If not, what factors are likely to have contributed to the lack of response? Are any visual symptoms of nutrient deficiency likely to be present?

Answer:

Appendix: Example of Calculating Fertilizer Application Rate

The most common application rate for nitrogen on the coast is 200–225 kg N/ha and slightly less for the interior at 175–200 kg N/ha. Note that the *application rate* is properly stated in terms of an amount of nutrient element applied. The actual amount of fertilizer material (prill) applied depends on the concentration of the element in the material.

For example, the fertilizer material – urea [$(NH_2)_2CO$] – is only 46% nitrogen by weight. Therefore, the amount of urea to apply to achieve the target rate of application of 200 kg N/ha is:

$$\frac{200 \text{ kg N/ha}}{0.46 \text{ N}} = 435 \text{ kg/ha}$$

For the interior, where ammonium sulphate [$(NH_4)_2SO_4$] may be used, the concentration of nitrogen is only 21% by weight. The amount to apply to achieve the target rate of application of 170 kg N/ha is:

$$\frac{170 \text{ kg N/ha}}{0.21 \text{ N}} = 810 \text{ kg/ha}$$

A blend of forest grade urea plus forest grade ammonium sulphate results in a target application rate of approximately 520 kg/ha. The percentage of elemental concentration can be calculated from the chemical formula using the atomic weights for each individual element or more easily determined from conversion tables. An example of a table for nitrogen (N), phosphorus (P) and potassium (K) is provided below. There are two common ways for fertilizers to be named – the fertilizer material name or the grade. For example, urea is the material name for a nitrogen fertilizer with a grade of 46-0-0, that is to say 46% N, 0% P_2O_5 (phosphate) and 0% K_2O (potash).

All fertilizers can be referred to by either their material name or grade. Single nutrient fertilizers are called "materials" or "simple" fertilizers. Multinutrient fertilizers are called "mixed fertilizers." Multinutrient fertilizers are given a numerical designation consisting of three numbers. This three-number designation is called a "grade." The numbers are the content of nitrogen, phosphate and potash in terms of percent by weight. A zero designation in a grade indicates that that particular nutrient is not included in the fertilizer.

Conversion tables are available to calculate the actual amount of an element source provided in a simple or mixed fertilizer.

Conversion Table

Fertilizer material	Grade	Element source	To convert from (multiple by)	
(A)		(B)	A→B	B→A
urea $CO(NH_2)_2$	46-0-0	N	0.4665	2.1437
ammonium nitrate NH_4NO_3	35-0-0	N	0.3500	2.8557
ammonium sulphate $(NH_4)_2SO_4$	21-0-0	N	0.2120	4.7169
triple superphosphate $Ca(H_2PO_4)_2$	0-45-0	P	0.1962	5.0968
superphosphate	0-20-0	P	0.0873	11.454
potassium chloride (KCl)	0-0-63	K	0.5229	1.9124
ammonium sulphate $(NH_4)_2SO_4$	21-0-0-24S	S	0.2426	4.1220
granular borate	0-0-0-14B	B	0.1430	7
borax $Na_2B_4O_7 \cdot H_2O$	0-0-0-11B	B	0.1134	8.8129

Note that both the P and K in the grade are not for percentage of these elements but for percentage by weight of phosphate (phosphorus pentoxide) and potash (potassium oxide), which are only in part composed of these elements.

Exercise to Determine Fertilizer Application Rates

Question #1

Show that it is more costly to apply ammonium nitrate fertilizer than it is to use urea. Assume that the growth response to a single application of 200 kg N/ha is the same for either form of N and that the cost per metric ton of material is $250/ha.

Answer:

Question #2

Show that the operational mix of 58% urea and 42% ammonium sulphate produces the blended fertilizer of 35-0-0-10S that is 35% N by weight. What is the application rate to achieve 175 kg N/ha + 50 kg S/ha?

Answer:

Question #3

For an operational trial, you have decided to use a blended fertilizer to correct the specific nutritional deficiencies discovered through screening trials. Your tree nutrition specialist recommends the application of 226 kg N/ha, 135 kg P/ha and 48 kg S/ha to address this forest nutrient problem.

What would be the combination of fertilizers to formulate such a blend, assuming it is best to use only urea (U), ammonium sulphate (AS) and triple superphosphate (TSP)? What would be the application rate of this mix?

Answer:

Checking Application Rate by Determining Swath Length and Drop Duration

Question #4

The coast version is in **bold** (interior version in parenthesis). The application of forest fertilizer by helicopter is frequently done using a Bell 205 equipped with a 1500 kg capacity spreader or hopper. The swath width has been determined at earlier calibration applications to be 60 m. If the target fertilizer material application rate with **urea** (urea + ammonium sulphate mix) is **450** kg/ha (510 kg/ha) and the swath overlap is for triple coverage, what is the estimated distance of each swath or run with the helicopter traveling at a ground speed of 90 km per hour? How long in minutes or seconds will it take to empty the spreader?

Answer: